Air Quality by Design

Harnessing the Clean Air Act to Manage Metropolitan Growth

Brian Stone Jr.

In the forty years since the passage of the original Clean Air Act, urban air quality has improved significantly in the United States. Less than a century ago, the vast quantity of coal smoke emitted by urban industries was sufficiently great to obscure the sun, often requiring street lamps in the largest industrial cities to remain lighted throughout the day. Urban residents waged a losing battle against the pervasive dust and ash that entered the home, while downtown merchants labored to keep their merchandise free of soot. More than an aesthetic nuisance, the thick air pollution was directly tied to a range of respiratory illnesses and was believed by civic and religious leaders to be at the root of a societal deterioration in morality (Boyer 1978). Perhaps the most lasting implication of industrial air pollution, however, was its influence on urban development patterns. "Smoke suppressed property values, as clean air became a selling point in the suburbs and dirty air became a reason to flee neighborhoods near city centers" (Stradling 1999, 30).

It is perhaps ironic that a century of urban decentralization has not succeeded in providing clean air for the majority of Americans. Many modern air quality problems have tagged along for the ride to the suburbs, undergoing a transformation from the localized stack emission to the regionalized by-products of vehicle travel, such as ground-level ozone and greenhouse gases.[1] Despite the substantial success of the Clean Air Act in reducing stack and tailpipe emissions through technological controls, 58 percent of the U.S. population resides in regions in which air pollution still exceeds national health-based standards (U.S. Environmental Protection Agency [EPA] 2001b, 10). It is estimated that between fifty and sixty thousand Americans die prematurely each year from air pollution–induced cardiopulmonary diseases, a fatality rate surpassing that of auto-related deaths in most large cities (Shprentz 1996, 1).[2]

The persistence of urban air quality problems in the United States may be attributed, in part, to the nature of control strategies that have been employed to combat mobile source air pollution. The predominant approach to achieving air quality standards over the past thirty years has been through the mandated development of increasingly effective emissions control technologies. While this approach has been highly effective in reducing emissions of vehicle pollutants per mile of travel, an increase in the number of vehicles owned and the number of miles driven per capita

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Abstract

This article examines the gradual emergence of an integrated technological and behavioral approach to mobile source emissions control in the United States. Confronted with the persistence of urban air quality problems in regions experiencing rapid population growth and decentralization, the Environmental Protection Agency recently developed a set of guidelines to permit metropolitan regions to receive air quality "credit" for the adoption of "smart growth" land use practices. Following an examination of the predominant emissions control philosophy that has guided federal air quality management for more than thirty years, the author outlines three stages in the existing air quality planning process through which metropolitan planning organizations may receive credit for land use–based control strategies and recommends a set of institutional changes needed to foster the development of an integrated land use, transportation, and air quality management framework.

Keywords: *air quality; planning; Clean Air Act; sustainable land use; smart growth*

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has diminished these improvements (U.S. EPA 2000). As evidence of a significant relationship between land use and vehicle travel increasingly has been documented, a growing number of voices have called for our technological approaches to air quality management to be complemented with spatial strategies designed to reduce vehicle travel (Downs 1992; Newman and Kenworthy 1999; Frank, Stone, and Bachman 2000). There is recent evidence that the regulatory climate is moving in this direction as well.

In January 2001, the EPA issued to little fanfare a new set of policy guidelines through which metropolitan regions in nonattainment with the National Ambient Air Quality Standards (NAAQS) may receive emissions "credit" for adopting sustainable "smart growth" land use practices (U.S. EPA 2001b). The development of these guidelines represents a significant departure from the federal government's established regulatory framework and a shift in policy that may open the door to a more direct role for land use planners in air quality management. In the interest of assessing the potential implications of these guidelines for planning practitioners, this article examines both the philosophical and programmatic aspects of air quality planning in the United States. In so doing, the article seeks to make two specific contributions to the emerging field of land use, transportation, and air quality planning.

First, the article presents a comprehensive overview of the federal government's approach to air quality management since the period of the mid-twentieth century. As the new smart growth provisions are incorporated into the established air quality planning framework, it is imperative that planning practitioners develop a working knowledge of the regulatory programs created by the Clean Air Act to control mobile source air pollution. To this end, the first component of the article explores the development of the federal air quality control program as a response to competing pollution control philosophies and the jurisdictional parameters of federal environmental management. I contend that the development of a growth-oriented strategy for emissions control is a response on the part of the EPA to the insufficiency of a purely technological approach to air quality management. An analysis of the major federal air quality control statutes provides a basis for identifying the shortcomings of the current management framework and for assessing the potential for the new guidelines to create a more balanced process.

The second objective of the article is to propose a number of institutional changes that are needed to develop a more fully integrated land use, transportation, and air quality planning process. Implemented at different levels of government and responsive to separate statutory mandates, the loosely related planning processes now in place are programmatically independent and, in a number of respects, structurally incompatible. While the EPA has identified three regulatory mechanisms through which the various planning processes may be linked, I argue that to be genuinely effective, an integrated planning framework will require additional policy and institutional changes. At a minimum, these changes entail a revision of federal funding eligibility requirements to include land use control strategies, a state-mandated balancing of traditional and land use control strategies in the transportation plan conformity determination process, and the incorporation of air quality management course work into graduate-level planning curricula.

▶ The Engineering of Air Quality

The first air pollution laws in the United States were enacted by municipal governments in response to public outcry over the nuisance of heavy industrial coal smoke. While cities such as Chicago, Cleveland, and New York had enacted smoke-abatement laws by the late nineteenth century, these early ordinances were rarely enforced and, as a result, failed to produce more than marginal improvements in urban air quality (Stradling 1999). Concerned over a rise in conflicts pertaining to interstate air pollution, as well as the increase in emissions from a rapidly growing fleet of automobiles, the federal government in 1955 passed the nation's first piece of federal air quality legislation, titled the Air Quality Control Act. Although its primary intent was to initiate a national research program to document the sources and effects of air pollution, the 1955 act established a fundamental tenet of air quality regulation that remains to this day: "The states and local governments are responsible for maintaining and improving air quality within their jurisdiction" (Erbes 1996, 5).

As with all forms of environmental regulation, the role of federal oversight in air quality management is greatly complicated by issues of jurisdiction. To account for the established primacy of state and local governments in matters of air quality control, the original Clean Air Act, enacted in 1963, outlined a collaborative relationship between federal, state, and local governments. The centerpiece of this legislation was a mandate requiring that the federal government establish health-based air quality criteria to be made available to states interested in formulating their own air pollution standards (Pub. L. 88-206, § 3[c][2]). Although the states were not required to use these criteria, the 1963 act established a clear division of labor in placing the responsibility for developing air quality goals on the federal government and the burden of program implementation on state and local governments.

Table 1.
Federal control mechanisms of the Clean Air Acts.

Title of Legislation	*Health-Based Standard*	*Mandated Technological Control*	*Mandated Nontechnological Control*
Air Quality Control Act of 1955	None	None	None
Clean Air Act of 1963	Advisory air quality criteria	None	None
Clean Air Act of 1967	Mandated adoption of state air quality standards	National vehicle emissions standards[a]	None
Clean Air Act of 1970	National Ambient Air Quality Standards (NAAQS)	90 percent reductions from 1970 models by 1975 for light-duty vehicles;[b] fuel requirements	None
Clean Air Act of 1977	NAAQS and prevention of significant deterioration standards (PSD)[c]	Extensions on 1970 Clean Air Act requirements; heavy-duty vehicle standards	None
Clean Air Act of 1990	NAAQS and PSD	Revised tailpipe standards; reformulated gasoline regulations; evaporative emissions controls; Clean Fuel Vehicle Program	Transportation control measures for serious, severe, and extreme nonattainment regions

a. This provision called for the promulgation of a uniform set of national vehicle emissions standards and further prohibited any state from adopting a more restrictive set of standards. Exceptions to this clause, however, were states that had enacted such standards prior to March 30, 1966. The only state meeting this requirement was California, which has maintained to this day a unique and more restrictive set of emissions standards (Schlesinger and Horowitz 1998).
b. More specifically, the 1970 Clean Air Act required that mobile source emissions of carbon monoxide and hydrocarbons (later referred to as volatile organic compounds) be reduced by 90 percent from 1970 levels by the 1975 model year. Vehicle emissions of nitrogen oxides were to be reduced by 90 percent from 1971 levels by the 1976 model year. Despite significant progress achieved through the development of catalytic converters, these goals were not attained.
c. The prevention of significant deterioration standards were enacted to maintain air quality in regions that had not exceeded the National Ambient Air Quality Standards.

Since the passage of the original legislation, the federal government's approach to air quality management has undergone a steady transition with each revision of the Clean Air Act. Confronted with a continuing deterioration in national air quality, Congress would require in the 1967 Clean Air Act the development and adoption of ambient air quality standards by each state (Pub. L. 90-148, § 107[b][1]) and the promulgation of national vehicle emissions standards (Pub. L. 90-148, § 202[a]). The 1970, 1977, and 1990 amendments to the Clean Air Act would further break from the advisory role initially prescribed for the federal government by replacing the nonbinding state standards with a national set of air quality regulations, the NAAQS (42 U.S.C. § 109), and requiring particular industries to develop emissions control technologies. The 1970 Clean Air Act, for example, established stringent tailpipe emissions standards that would require the development of catalytic converters for all automobiles manufactured beginning in the 1975 model year (U.S. EPA 1994). Although state and local governments remain free to use other approaches to achieve emissions reductions, the use of various control technologies has increasingly emerged as a mandatory requirement for compliance. Table 1 lists examples of emission control programs mandated by each of the air quality control statutes from 1955 to 1990.

The technological provisions of the post-1963 revisions of the Clean Air Act embody a subtle but significant shift in the federal government's approach to air quality planning, one that has had important implications for the success of air quality regulation. With each amendment to the act, Congress has broadened the oversight role of the federal government in developing strategies to improve national air quality. Initially charged with the limited responsibility of establishing a set of health-based standards for state and local governments to achieve through whatever means deemed effective, the EPA has been further empowered to promulgate emissions standards for particular industrial processes and mobile sources and to mandate the development and use of specified emissions control technologies (Erbes 1996). The primary reason for granting the EPA a programmatic role under the Clean Air Act was to facilitate the formulation of a uniform set of emissions standards with which industries in all regions of the country must comply. Prior to the codification of these provisions, individual states such as California enacted emissions standards in excess of those adopted by other states, placing

industry in these states at a distinct competitive disadvantage (Bryner 1993).

The significance of a shift in federal priorities from policy formulation to program implementation lies in the nature of strategies that the EPA is empowered to formally mandate. The universe of emissions control strategies consists of three general approaches: (1) reducing the rate of pollutant emissions from a particular activity, (2) transforming the type of emission to a less harmful pollutant, and (3) limiting the emissions-producing activity (Boubel et al. 1994). In the context of mobile source emissions control, the first two of these options are achieved through the development of emissions control technologies. The third option requires a change in individual patterns of travel behavior. Although state and local governments are empowered to enact programs designed to alter travel behavior, the federal government has emphasized technological controls. As a result, state emissions reduction programs generally rely on a purely technological approach to air pollution control until they are "bumped up" to one of the highest levels of nonconformity.[3] There are three general reasons for this trend:

- Limitations on federal oversight: as first exemplified in the Air Quality Control Act of 1955, Congress has repeatedly acknowledged the primacy of state and local governments in the realm of air quality management. One means of sidestepping direct intervention in intrastate matters has been through regulation of national corporations, such as automobile manufacturers and petroleum companies, at the point of production, rather than direct regulation of state and local governments.
- Administrative feasibility: the Clean Air Act requires that the pollution control measures included in state implementation plans (SIPs) exhibit the characteristics of quantifiability, enforceability, replicability, and accountability (Wyman and Kato 1998). An engineering-based approach to emissions control is generally better suited to these constraints than is one designed to alter travel behavior. In addition, it is undoubtedly more feasible to regulate the emissions control techniques of a limited number of industries than to influence the travel decisions of a large number of individuals.
- Political feasibility: Congress and the EPA have long been wary of the political ramifications of legislating and regulating the behavior of individuals. Although the costs of controls may be passed along to consumers, the political liability of a technological mandate is generally assumed to be much less than that of a "big brother" approach to influencing travel behavior and energy consumption (Bryner 1993).

Although perhaps more attractive from an administrative and political vantage point, the disadvantage of a strictly technological control program is that it may fail to achieve an air quality standard when the technology is inadequate or when patterns of individual consumption change. As Bryner (1993) notes, Congress and the EPA have struggled with this issue over time in subsequent revisions of the act:

> Two approaches, national ambient air quality standards and technological controls, have been emphasized at different times throughout the history of the Clean Air Act. The first approach entails determining what levels of pollution do not pose a health risk and then what reductions in pollution are needed to achieve those standards. The second approach—simply requiring all sources to install pollution control equipment—has usually been easier to implement. Critics of national ambient air quality standards argue that they are too complicated and difficult to enforce, but at least the approach does focus on air quality and the health risks involved. Technological controls may not always lead to achievement of air quality standards or protection of human health. (P. 150)

In other words, the federal government has wavered over time between an ends-oriented and a means-oriented approach to air quality planning.[4] The shortcoming of a means-oriented approach to air quality planning is clearly reflected in our efforts in the realm of mobile source air pollution control. As mandated by each of the 1967 to 1990 Clean Air Acts, automobile manufacturers have been required to develop increasingly effective emissions control technologies to reduce the rate of pollutant emissions per mile traveled. The success of this effort in reducing the rate of vehicle emissions has been outstanding, achieving reductions of approximately 90 percent since the 1970 model year (U.S. EPA 2000).[5] Yet due to the fact that our control program has failed to address the growth in vehicle trip generation and the number of miles traveled annually, the success of this emissions program has been greatly offset by increases in per capita vehicle travel. As a direct result, ozone formation, particulate matter, and carbon monoxide problems have persisted—and, in a few cases, intensified—within a number of metropolitan regions (U.S. EPA 2000).

Figures 1 and 2 illustrate the impacts of federal air quality control programs on tailpipe emissions and urban air quality nationwide. In the first graph, the nation's success in reducing vehicle emissions per mile of travel since the 1967 act is clear. Yet a substantial increase in the number of miles traveled annually has greatly offset the benefits of these reductions. For example, between 1970 and 1999, average vehicle emissions of hydrocarbons per mile of travel decreased by almost 90 percent (U.S. EPA 2000), yet total hydrocarbon emissions from the light-duty vehicle fleet decreased by only 31 percent (U.S. Department of Energy 2002). This discrepancy between the per mile and total fleet emission reductions can be attributed to the dramatic increase in total annual vehicle miles of travel (VMT) depicted in Figure 1. Perhaps most significant, Figure 1 illustrates that while the country's technological control

program is entering a stage of diminishing returns, annual VMT are projected to continue growing rapidly through 2015.

Nationally, the EPA's air quality control efforts have yielded mixed results since the passage of the 1990 Clean Air Act amendments. Figure 2 illustrates the annual mean number of days in violation of the national ozone standard for major urbanized regions between 1990 and 1999. The most pervasive urban air quality problem in the United States, ground-level ozone (i.e., urban smog), has been directly linked to a wide range of respiratory conditions, including acute asthma, immune system impairment, and a reduction in life expectancy on the order of years (Touloumi et al. 1997). Despite ongoing technological improvements in emissions control during this period, the average number of days in violation of the national ozone standard did not decrease consistently during the 1990s and was actually higher in the final year of this decade than in the first. As the central objective of the Clean Air Act is to improve air quality on an annual basis, this ten-year trend raises important questions about the recent success of our technologically based emissions control program and may indicate the need for a more balanced approach to urban air quality management.

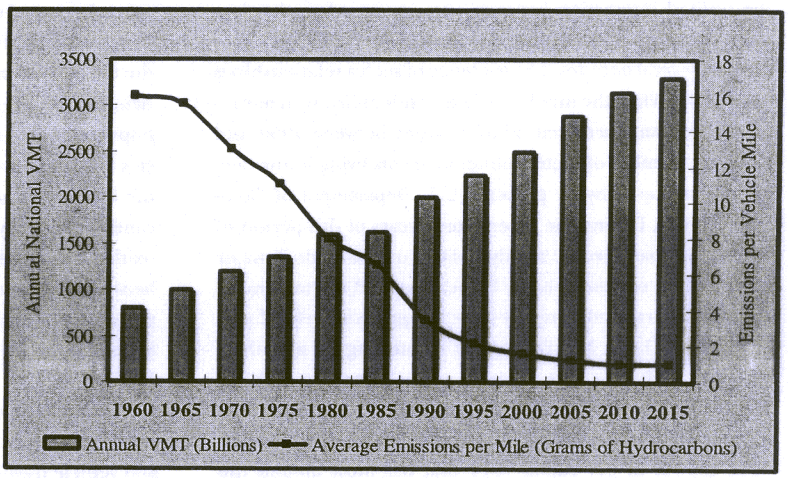

Figure 1. *National trends in vehicle travel and emissions per mile.*
Source: Adapted from U.S. Environmental Protection Agency (2001a).
Note: VMT = vehicle miles of travel.

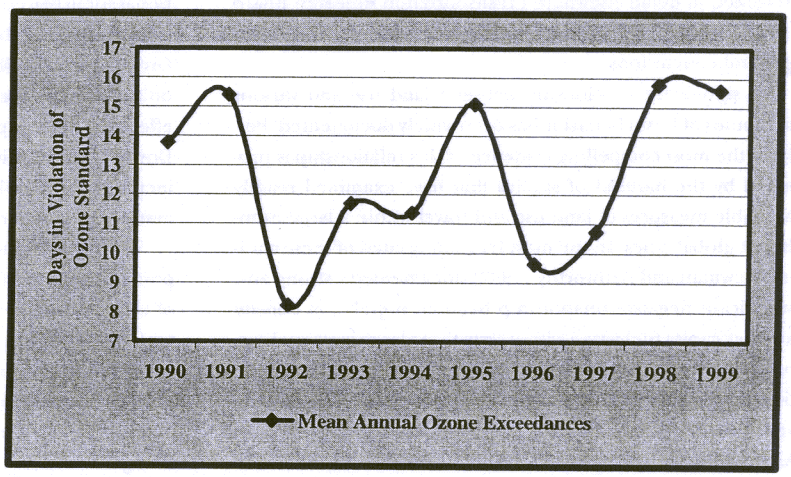

Figure 2. *Mean number of days in violation of the national ozone standard for major U.S. cities between 1990 and 1999.*
Source: U.S. Environmental Protection Agency (2000).
Note: Data include all metropolitan statistical areas with populations greater than 350,000 and mean exceedance observations between the 5th and 95th percentiles.

► The Significance of Land Use to Air Quality

Confronted with the incomplete success of a technologically based emissions control program, the EPA and state air agencies have increasingly employed strategies targeted at reducing the number of miles traveled in addition to controlling the emissions per mile. Couched in the somewhat technical phrases of *employer-based transportation management, traffic flow improvement programs,* and *multiple occupancy vehicle programs,* the Clean Air Act amendments of 1990 outline a number of transportation control measures that may be adopted by state and local governments to alter individual travel behavior in some fashion (42 U.S.C. § 108[b][2][e]). For regions that have fallen into the three highest categories of nonattainment for ozone, the EPA is required to mandate the adoption of such measures, leveraging federal transportation dollars as a stick to discourage continued noncompliance (42 U.S.C. § 179[b][1]).

A notable omission from the list of recommended transportation control measures is programs designed to offset vehicle travel over the long term through growth management. The appeal of what I shall term a *land-based* control strategy lies in

the posited interaction between changes in urban development patterns and the explosive growth in per capita VMT over the past several decades. The evidence of such a relationship is impressive. While the number of U.S. residents living in metropolitan regions increased by 37 percent between 1950 and 1990, the number of metropolitan residents living in the central city dropped by 31 percent (U.S. Department of Commerce 1993). During the latter fifteen years of this period of suburban expansion, the number of cars on the roads of major metropolitan regions grew by 50 percent, and the total number of miles traveled annually grew by approximately 62 percent (Downs 1992, 10). Even when accounting for growth in population during this period, annual per capita VMT increased by an astonishing 52 percent within large metropolitan regions (Downs 1992, 11). As noted above, it is this dramatic growth in per capita VMT that has most limited the effectiveness of tailpipe emissions control programs.

To verify the significance of potential land-based control strategies, a number of studies have sought to statistically associate land use and travel behavior. As these studies have been reviewed in detail elsewhere (Transportation Research Board 1995; Apogee 1998), I shall not do so here except to note a few general conclusions.

A significant relationship between land use and various attributes of travel behavior has been widely documented. Perhaps the most compelling evidence of this relationship is provided by the handful of studies that have examined readily available measures of land use and travel within a large number of global cities. In the most frequently cited of these studies, Newman and Kenworthy (1999) documented a strong and significant negative relationship between population density and per capita fuel usage within sixty-three large metropolitan regions around the world ($R^2 > .85$).[6] Similar significant relationships have been found to exist between population density and vehicle ownership, vehicle trip generation, and VMT in American cities and abroad (Dunphy and Fisher 1994; Pucher and Lefevre 1996).

In contrast to these widely cited multicity studies, projects employing travel simulation models or household travel survey data from a single metropolitan region have yielded less conclusive results. Of eighteen studies of this nature reviewed by the author, fifteen documented a statistically significant relationship between the density of development, the intermixing of land uses, and/or the configuration of the street network and some measure of vehicle travel (e.g., Frank and Pivo 1994; Holtzclaw 1994; Cervero and Gorham 1995). For example, in a study of land use and vehicle travel in the Sacramento, California, region, Johnston et al. (2000) found the combined impacts of transit improvements and land use strategies to reduce VMT by between 4 percent and 7 percent over twenty years. In one of the most widely cited studies of this nature—the Land Use, Transportation, and Air Quality Analysis conducted in Portland, Oregon—a development scenario emphasizing transit-oriented development, pedestrian infrastructure improvements, and transportation demand management policies was found to reduce daily VMT by 7.9 percent relative to the business-as-usual scenario of highway expansion. Significantly, this study also found vehicle emissions of nitrogen oxides, hydrocarbons, and carbon monoxide to be reduced by between 2.6 percent and 6.7 percent through a transit- and pedestrian-oriented development strategy (Cambridge Systematics and Parsons, Brinkerhoff, Quade, and Douglas 1996).

A somewhat smaller, although no less compelling, set of empirical studies has found the relationship between land use and vehicle travel behavior to be insignificant or weak. In her examination of trip generation in low- and high-accessibility neighborhoods, for example, Handy (1992) found no statistically significant difference in the number of vehicle trips generated for regional travel within traditional urban and conventional suburban communities. In assessing the influence of the jobs-to-housing balance on average commute distance, Giuliano and Small (1993) found that while negatively related, only extreme levels of imbalance produced a measurable effect on work trip distance. Likewise, citing evidence from Downs (1992), Giuliano (1995) concludes that substantial increases in population density are required to effect only marginal reductions in work trip VMT.

While the weight of the empirical evidence appears to support a linkage of varying strength between the physical design of cities and travel behavior, there remain at least two important uncertainties regarding the viability of a land-based approach to air quality management. The first of these pertains to the magnitude of regional air quality benefits that potentially may be realized through incremental land use change. While there is compelling empirical evidence to suggest that measurable reductions in vehicle travel can be achieved at the project or neighborhood level, only a handful of studies has sought to extrapolate these benefits to the level of the region. As the majority of land use within large metropolitan regions is fixed for the near to medium term, there is a need for more evidence to realistically assess the magnitude of regionwide reductions in travel that may be accomplished through incremental, and often peripheral, land use change (Giuliano 1995).

A second important limitation common to many empirical assessments of land use and vehicle travel is a failure to explicitly control for the existence of pricing measures and other transportation demand management policies in place within alternative development patterns. For example, the influential

Newman and Kenworthy (1999) study cited above fails to account for the role of vehicle taxes and parking costs as a determinant of per capita gasoline consumption in global cities. A failure to explicitly account for pricing policies as distinct from physical design may promote the unsubstantiated conclusion that land use changes can bring about significant reductions in vehicle travel in the absence of such mechanisms. Indeed, this assumption seems to be at the heart of many new urbanist proposals.

Nevertheless, the regional VMT simulation studies cited above indicate that a combined strategy of transit-oriented development and transportation demand management has the potential to effect reductions in regional vehicle travel over time. While the projected air quality impacts of a comprehensive smart growth program remain modest relative to what has been accomplished through technological controls, there is sufficient empirical evidence to suggest that land-based measures provide a viable strategy for at least stabilizing the growth in VMT. If accurate, land-based control strategies may be regarded as an essential complement to our means-oriented technological control program; that is, by serving to stabilize annual growth in VMT, growth management policies can permit the full benefit of emissions controls to be realized.

▶ Promoting Sustainable Land Use through the Clean Air Act

In recognition of the potential for land use strategies to stabilize or moderately reduce regional vehicle travel over time, the EPA is exploring options to promote patterns of "sustainable land use" within the regulatory framework of the Clean Air Act.[7] The EPA defines sustainable land use as "a variety of policies and programs that aim to provide attractive and safe places to live and work, minimize the use of natural resources, and allow for alternatives to vehicle travel" (U.S. EPA 1999, i). Meeting this objective is made difficult, however, by the well-established precedent of local government discretion in matters of land use regulation. Recognizing the ultimate significance of land use to urban air quality, Congress opened the door to limited federal oversight of land use planning in the 1970 Clean Air Act. In outlining the requirements for an acceptable SIP, the act indicates that such plans must include "emission limitations, schedules, and timetables for compliance with such limitations, and such other measures as may be necessary to ensure attainment and maintenance of such primary or secondary standard, including, but not limited to, land-use and transportation controls" (Pub. L. 91-604, § 110 [a][2][B]).

This provision, however, was repealed in the 1977 Clean Air Act amendments, in which Congress maintained the authority of the EPA to require transportation measures but struck any mention of land use from the legislation entirely. The legislative history from the 95th Congress indicates that the majority had an interest in prohibiting the EPA from "compelling any state to impose any uniform or automatic no growth buffer zone around any area" (H. Rep. No. 95-294, at 8 [1977], reprinted in 1977 U.S.C.C.A.N. 1077, 1085). In short, Congress determined that issues of growth management should be deliberated at the local level of government. The 101st Congress would close the door on this issue by adding to the 1990 Clean Air Act the following section, titled "Land Use Authority": "Nothing in this Act constitutes an infringement on the existing authority of counties and cities to plan or control land use, and nothing in this Act provides or transfers authority over such land use" (42 U.S.C. 131).

While the EPA lacks land use authority, state and local governments retain the option of regulating land use as a means of improving air quality. What remains unclear is how potential land-based control strategies should be incorporated into the EPA's air quality review process. The EPA envisions two basic roles for federal involvement in the land use planning of local governments. First, the agency is in a position to establish a set of uniform guidelines to be used by state air quality agencies in evaluating the pollution reduction potential of various sustainable land use strategies. As a centralized body, the EPA can play a role in setting nonmandatory, uniform goals and distributing information to the states on what types of land use strategies are likely to be most effective in improving air quality. Second, by formally recognizing and quantifying the benefits of sustainable land use to air quality, the EPA can award credit to regions currently in nonattainment that adopt sustainable land use practices in comprehensive land use plans. In so doing, the federal government can provide an incentive for local governments to incorporate air quality criteria into long-range plans and can further enhance the range of implementation options available to regions that have lapsed into nonconformity (U.S. EPA 2001a).

▶ Accounting for the Air Quality Benefits of Land Use

The EPA has identified three policy options through which municipal and regional governments may receive air quality credit for sustainable land use practices. Although prohibited from regulating land use directly, the agency's authority over federal transportation funding provides a powerful tool for

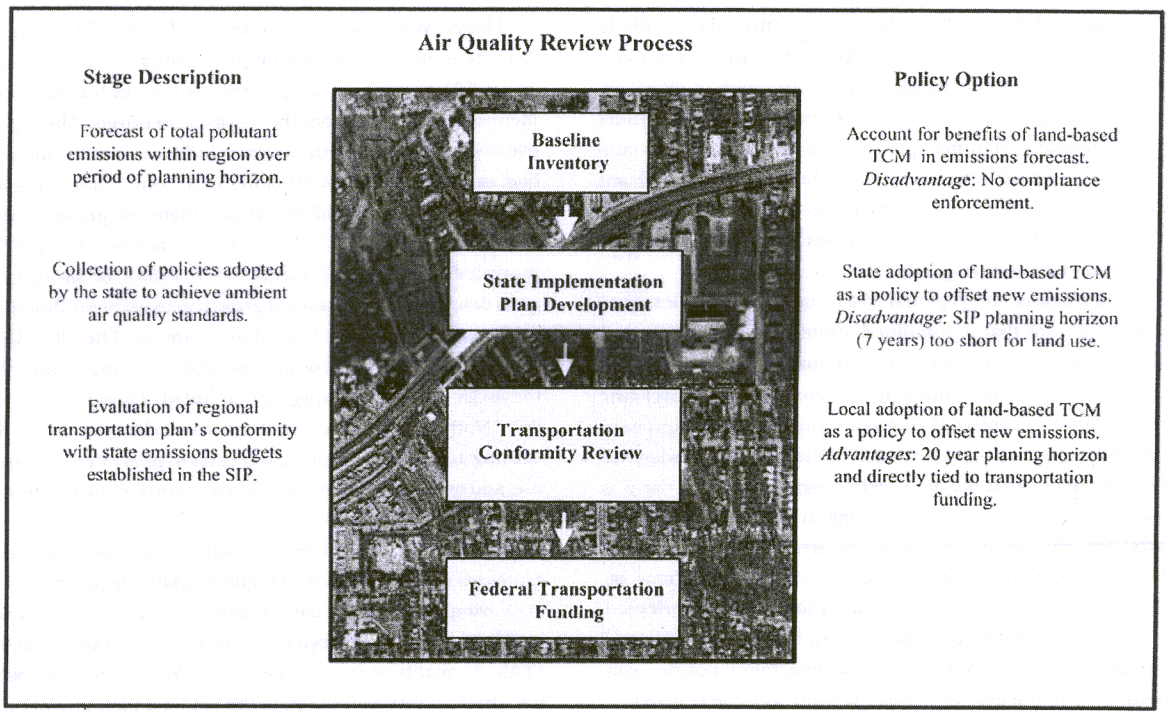

Figure 3. *Policy options for land-based transportation control measures.*
Note: SIP = state implementation plan; TCM = transportation control measure.

encouraging regions in nonattainment to take actions believed to be effective in attaining air quality standards. The challenge for the EPA is to incorporate land use objectives into existing regulatory programs without encroaching on the jurisdiction of local governments to manage their own growth.

In a document titled "EPA Guidance: Improving Air Quality through Land Use Activities," the U.S. EPA (2001a) examines three stages of the existing air quality planning process through which the air quality benefits of a land-based control strategy could be measured. These stages include the formulation of a state baseline emissions inventory, the development of a SIP, and the transportation plan conformity determination process. Each option identified and its implications for the planning process are presented in Figure 3.

Accounting for Land Use in the Baseline Inventory

The first stage of the state air quality planning process involves the development of an emissions baseline inventory for all regulated pollutants. This process requires the state air-planning agency to forecast the current and expected emissions of regulated air pollutants from all sources within the state over a specified number of years.[8] To develop the baseline inventory, metropolitan planning organizations (MPOs) must forecast changes in population growth, employment, and vehicle travel that are expected to occur within their respective jurisdictions. Once the projected travel demand is determined, the state air-planning agency is responsible for estimating the quantity of mobile source emissions expected to result from the annual travel demand forecast.

One option identified by the EPA is to permit the benefits of a sustainable land use measure to be assessed during the initial baseline inventory stage. Were MPOs to account for the vehicle travel reductions projected to result from a sustainable land use project, the corresponding baseline estimate of the region's total mobile source emissions would be reduced. A reduction in the baseline inventory would, in turn, reduce the quantity of emissions that would need to be controlled by a metropolitan region to comply with federal air quality standards. A significant disadvantage of this approach, however, is that the policies and programs assumed by the baseline forecasting process to be in place are not subject to review or

enforcement by the EPA. As a result, there would be no guarantee that the programs incorporated into the baseline forecast would actually be implemented by state and local governments.

Accounting for Land Use in the SIP

The second stage within which air quality credit may be awarded for sustainable land use is within the SIP development process. Following the establishment of a statewide emissions forecast, the state must develop a control program to ensure that the NAAQS are not violated by the projected increase in transport emissions. The range of control measures selected and the guidelines for their implementation are spelled out within the SIP (Wyman and Kato 1998). It is within the SIP document that the maximum allowable vehicle emissions, or the mobile source emissions "budget," are specified. One means of offsetting expected emissions would be through the inclusion of a land-based control strategy within the collection of emissions control strategies called for in the SIP. Under this scenario, the initial baseline inventory outlined above would be derived without any consideration of the travel reduction potential of particular land use measures. The inclusion of specified land-based control measures within the SIP would then qualify a region for an emissions credit, thus reducing the total quantity of emissions required to be abated through technological (e.g., reformulated gasoline) or conventional transportation control measures (e.g., carpooling programs).

Although this second approach would produce essentially the same outcome as the initial baseline option, the SIP review process requires that each control strategy adopted be directly tied to an enforcement mechanism, hence further ensuring compliance. A primary limitation of the SIP option, however, is the relatively short five- to seven-year planning horizon of implementation plans adopted by regions currently in violation of air quality standards. Over this period of time, it may not be possible to fully realize the long-term benefits of a land-based transportation control measure, thus discounting the utility of this approach relative to others with shorter term benefits.

Accounting for Land Use in the Conformity Determination

A final program component within which to assess the benefits of sustainable land use is the transportation plan conformity determination process. The conformity determination process requires each MPO to estimate the annual emissions generated by mobile sources as part of a long-range transportation plan.[9] In contrast to the baseline emissions inventory, the transportation plan forecasts emissions over a longer planning horizon—typically twenty years—and accounts for the effects of land use changes during this period. In order for a region to achieve transportation conformity, new projects included in the transportation plan must comply with the mobile source emissions budget established by the SIP.

Metropolitan regions currently in noncompliance with the NAAQS could mitigate long-range emissions forecasts through the adoption of land-based control strategies in transportation plans. As a conformity demonstration is necessary to qualify for federal transportation funds, local governments would likely be interested in implementing a land-based control strategy that could directly contribute to conformity success. In addition, the longer planning horizon of the transportation plan is sufficient to permit the benefits of a land use measure to be realized. Because a transportation plan must be found to conform to a region's emission budget for each of the twenty years modeled, land-based strategies projected to yield significant results in Years 10 through 20, for example, would contribute to conformity success. This option is also appealing in that in addition to the creation of a transportation plan, the conformity review coincides with the development of a long-range land use plan for the region. The existence of an integrated land use and transportation planning process provides the ideal opportunity to associate land use decisions with future air quality.

In light of these advantages, the transportation conformity stage is the option clearly favored by the EPA as the point at which to formally incorporate sustainable land use into the air quality planning process.[10] Although the adoption of any approach remains optional to metropolitan regions, the possibility of achieving transportation plan conformity through sustainable land use will undoubtedly appeal to regions that would otherwise face a funding moratorium. It is also important to note that many regions are currently adopting similar land use techniques to achieve non–air quality objectives. As reported by Southworth (1997), a number of "new urbanist" communities have restructured existing land development regulations to promote alternatives to vehicle travel and a greater sense of community. Other authors have demonstrated the benefits of urban densification and clustered patterns of development for the protection of agricultural areas (Nelson 1992) and wildlife habitat (Odell, Theobald, and Knight 2003).

Despite these advantages, the initiation of a land-based air quality control program undoubtedly creates a number of administrative and political obstacles for the EPA to confront. On the administrative side, estimating the emissions benefits

of land-based control strategies presents a task of great technical difficulty. The models currently used to quantify vehicle emissions from land use and transportation projections remain somewhat crude in design and are vulnerable to challenges as to their accuracy (Jack Faucett Associates 1998). In addition, due to the unpredictability of market forces related to urban development, there is no guarantee that policies adopted to promote sustainable land use would result in actual changes on the ground.

On the political side, the decision of the EPA to participate in local growth management decisions, however indirect and advisory a role the agency may assume, is bound to be challenged by stakeholders with an interest in contemporary patterns of growth. A long-held tradition of individual property rights and local government discretion in matters of land use remains strong in the United States, and its advocates are generally hostile to perceived federal encroachment. Consequently, the sustainable land use policy will likely face both legal and political challenges down the road.

▶ Establishing an Integrated Land Use, Transportation, and Air Quality Planning Process

The challenges facing the EPA as it attempts to assert a role for itself in the divisive arena of growth management are substantial. Perhaps more significant than the administrative and political hurdles addressed above are the complications created through the jurisdictional divide between goal setting and program implementation outlined by the Clean Air Act itself. While the efforts of the EPA to bring the issue of land use to the forefront of environmental planning are laudable, the potential for achieving substantial gains through the federal air quality planning process alone may be limited. The reason for this is that land use remains strictly within the purview of local—and, in a few cases, regional—governments. As a result, any role the EPA assumes within this area must be regarded as advisory in nature. A more effective approach would involve local and regional governments' adoption of urban air quality standards as a distinct goal, permitting air quality to be planned for in direct conjunction with planning for land use.

While municipal governments have not traditionally incorporated air quality considerations into the land use planning process, the development of guidelines to enable metropolitan regions to receive sustainable land use credits creates a number of important incentives for local and regional governments to do so. The most evident of these incentives pertains to the increased flexibility that land-based strategies provide to nonattainment regions confronted with difficult conformity determinations. Such land use control strategies equip metropolitan regions with an alternative set of planning tools that may be employed to demonstrate conformity and thereby avoid a moratorium on federal transportation dollars. As noted above, a second important incentive for metropolitan regions to develop land-based control measures concerns the diversity of benefits that may be realized through sustainable land use projects. There is evidence that land use patterns most commonly associated with reductions in vehicle emissions also tend to reduce traffic congestion (Kulash 1991), improve mobility (Cervero 1998), increase community interaction (Putnam 2000), and enhance other environmental attributes of cities (Beatley 2000). The development of sustainable land use credits provides an additional incentive for metropolitan regions to accomplish a range of environmental and social objectives through growth management.

Despite these potential benefits of an integrated land use, transportation, and air quality planning program, local and regional governments are unlikely to institute significant changes in the established land use planning process without stronger incentives from federal and state governments. Because most local planning agencies are ill equipped to assess the implications of various land use strategies for regional air quality, there is a need for additional financial resources and air quality expertise to facilitate the development of a more integrated planning framework. Three institutional changes that may prove effective in this regard include (1) a broadening of federal transportation funding eligibility requirements to include land use strategies, (2) a state-mandated balancing of traditional and land use control strategies in transportation plan conformity determinations, and (3) the incorporation of air quality management course work into graduate-level planning curricula.

Federal Transportation Funding Eligibility

Although the federal government lacks the authority to require nonattainment regions to adopt sustainable land use policies, the EPA and the U.S. Department of Transportation could leverage federal transportation dollars to encourage a more balanced approach to air quality management. Restructured in the early 1990s to more equitably distribute federal transportation dollars between highway, transit, and nonmotorized projects, the federal transportation funding program, now known as the Transportation Equity Act for the 21st Century (TEA-21), provides resources for a range of projects designed to improve metropolitan air quality.[11] For

example, the Congestion Mitigation and Air Quality (CMAQ) program, an element of TEA-21, allocates funding to nonattain- ment areas seeking to improve regional air quality through transit system infrastructure upgrades. A broadening of project eligibility under CMAQ to include land-based control strategies would provide a direct financial incentive to county and municipal governments interested in reducing vehicle emissions through transit and pedestrian supportive development.

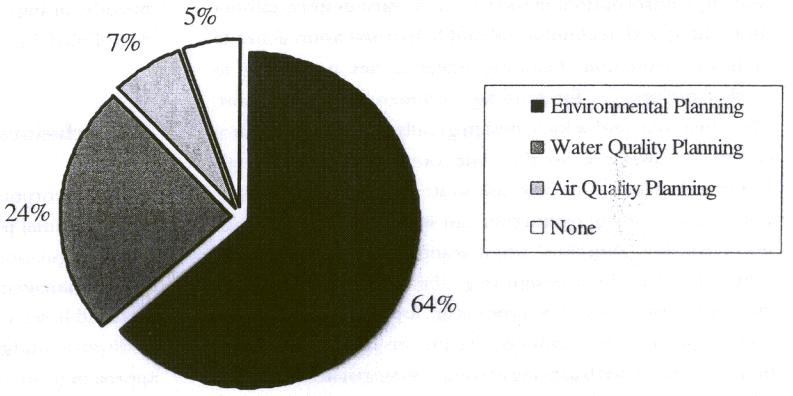

Figure 4. Environmental course offerings of accredited planning schools.
Note: Information on course offerings was obtained from sixty-five of sixty-nine accredited planning programs in the United States and Canada. Courses were categorized based on course titles and course descriptions, when available.

While the CMAQ program currently funds capital-intensive transit projects, such as the acquisition of alternatively fueled buses, no monies are available to encourage higher density development or street-scale improvements in proximity to transit stations. A broadening of eligibility requirements to include land use strategies would provide a strong complement to the EPA's new sustainable land use guidelines. At the very least, federal funding should be made available to offset the vehicle travel demand–inducing aspects of road expansion and construction projects funded through the highway construction and expansion elements of TEA-21. As demonstrated by a growing number of studies (Hansen and Huang 1997; Cervero 2003), the expansion of roads in proximity to urban areas directly influences the timing and scale of new development, fueling the phenomenon of road-induced travel demand. One potential means of slowing this process would involve the public acquisition of land or development rights in proximity to new federally funded road projects. Found to be an effective tool for protecting scenic view sheds in proximity to roadways (Ohm 2000), development rights acquisition is consistent with the EPA's criteria for a sustainable land use measure but likely presents a prohibitively expensive option for state and local governments. An expansion of TEA-21 eligibility requirements to include the acquisition of land and development rights would increase the feasibility of this approach for constraining growth along roadway corridors.

State-Mandated Balancing of Control Strategies

A second important institutional change needed to facilitate integrated land use, transportation, and air quality planning is a mandatory balancing of traditional and land use control strategies in transportation plan conformity determinations. While the EPA does not have the authority to require MPOs to adopt land-based control strategies, state governments have the power to modify the regional land use and transportation planning process and should do so to improve the likelihood of conformity success. By requiring MPOs to complement traditional control strategies (such as the use of reformulated gasoline or the establishment of vehicle inspection and maintenance programs) with land use strategies, states can effectively create a fully integrated framework for land use, transportation, and air quality planning at the regional level.

Today, most metropolitan regions employ a sequential transportation demand forecasting process through which land use assumptions are developed in the first stage of modeling and are presumed to remain fixed over the planning horizon. Rather than modify these land use assumptions in response to a failed conformity determination, MPOs most often adopt traditional, technological control strategies to offset additional mobile source emissions. By mandating that excess emissions be offset, in part, through land use strategies, states can ensure that land use will both inform (as modeling assumptions) and respond to (as control strategies) transportation system investments, creating a more integrated approach to regional land use, transportation, and air quality planning and ensuring a greater degree of coordination between regional transportation and local land use planning agencies.

A state-mandated balancing of traditional and land use control strategies would further permit metropolitan regions to

diversify control options in the face of the various uncertainties inherent to both technological and behavioral approaches to emissions reduction. Planning uncertainties pertaining to market preferences for housing, commercial development, travel behavior, and vehicle design greatly complicate the process of controlling regional mobile source emissions through either technological or land use strategies. Hence, the adoption of both control techniques can serve to moderate emission reduction "shortfalls" when assumptions regarding individual tastes in vehicle design (e.g., the rapid growth in sport utility vehicles) or travel behavior (e.g., low transit ridership in transit-oriented developments) are proven invalid over time. In short, a mandated balancing of control strategies would require MPOs to hedge their bets in response to market uncertainties, improving the likelihood of conformity success over time.

Incorporating Air Quality Management into Planning Curricula

A final institutional change needed to facilitate a more integrated approach to land use, transportation, and air quality planning is the incorporation of air quality course work into graduate planning curricula. Evidence suggests that planning graduates as a group are poorly prepared to address the air quality implications of land use decisions. By way of illustration, a survey of planning curricula conducted by the author in 2000 found that only 7 percent of all accredited programs in North America offer specialized course work in air quality planning. Presented in Figure 4, these findings highlight a general lack of emphasis on air quality and climatological issues in contemporary planning education. Interestingly, North American planning schools are about three times more likely to offer specialized course work in water resources planning than in air quality management.

As the linkages between urban land use and regional air quality in the technical literature grow increasingly apparent, it is imperative that students with an emphasis in environmental or transportation planning be prepared to assess the regulatory and environmental implications of urban development projects. In addition to developing specialized course work, planning schools can advance integrated approaches to land use and environmental planning through the development of short courses for planning practitioners and through the coordination of collaborative research between the social and the physical sciences. Beyond providing the methodological tools required to assess the atmospheric effects of land use and transportation decisions, interdisciplinary programs can provide an important counterpoint to the institutional segregation of planning processes found outside of universities.

▶ Conclusions

The incorporation of sustainable land use into the federal environmental planning process signals the emergence of air quality regulation as a potentially significant tool to promote growth management. It is important to emphasize, however, that land-based control strategies are not intended by the EPA to displace traditional technological controls as the primary approach to air quality management. While a number of studies have demonstrated a significant link between urban form and vehicle travel, the strength of these relationships is generally too weak to support an abandonment of conventional approaches to emissions control. Rather, sustainable land use strategies may be employed over the medium to long term to slow the rate of growth in metropolitan vehicle travel, permitting the potential of technological emissions controls to be more fully realized. To this end, the new smart growth guidelines lay the regulatory groundwork for local and regional governments to incorporate air quality criteria into the established land use and transportation planning process. This shift in policy represents an approach to air quality management that is fundamentally distinct from that of the past three decades. It is an approach that seeks to address the spatial source of mobile source air pollution in addition to its technological symptoms. Ultimately, it is only by addressing both sides of the emissions production equation that significant progress in the realm of air quality management may be realized.

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▶ Notes

1. Mobile sources account for more than 50 percent of the ozone air quality problem in most large metropolitan regions of the United States (U.S. EPA 2000). It is important to note, however, that point sources continue to play a significant role in the formation of both ground-level ozone and greenhouse gas production.

2. This estimate is based on mortality factors derived from the Harvard Six Cities Study. The study tracked more than eight thousand residents of six U.S. cities for between fourteen and sixteen years. Controlling for a range of demographic and behavioral factors (e.g., smoking), residents of the most highly polluted cities were found to have a premature mortality rate 26 percent greater

than residents of the least polluted cities. It should be noted that ambient air quality levels within each of the six cities studied were well within ambient air quality standards (Cotton 1993).

3. The 1990 Clean Air Act amendments specify various levels of nonattainment for tropospheric, or ground-level, ozone. As a metropolitan area advances to a more extreme level of standard violation, the requirements for emissions control become more stringent. For the three highest categories of ozone nonattainment—serious, severe, and extreme—metropolitan regions must enact transportation control measures to reduce vehicle travel. Presently, there are twenty-five regions categorized as serious, severe, or extreme nonattainment regions.

4. While the 1990 Clean Air Act amendments specify both ambient air quality standards (i.e., an ends-oriented approach) and vehicle emissions standards (i.e., a means-oriented approach), the statute's primary enforcement mechanism, a moratorium on federal highway funding, is tied to a failure todevelop a plan or demonstrate progress toward attainment of the National Ambient Air Quality Standards, rather than to actual standard attainment. Thus, because the Environmental Protection Agency has viewed the adoption of technological controls as evidence of progress toward attainment, the act's primary emphasis can be characterized as oriented toward the means rather than the ends of standard attainment.

5. While empowered to regulate the emissions of all mobile sources, the Environmental Protection Agency has not sought to regulate emissions from heavy-duty (commercial) trucks as aggressively as emissions from light-duty vehicles. As a result, heavy-duty trucks presently account for approximately one-third of the ozone precursors emitted from all mobile sources (U.S. Department of Energy 2002). The recent promulgation of more restrictive diesel emission regulations is designed to more effectively control these ozone precursors.

6. It should be noted that the Newman and Kenworthy (1989, 1999) study has been challenged on methodological grounds pertaining to the authors' failure to control for demographic influences and the use of inherently related compound variables in the analysis. For a more thorough discussion of these critiques, see Brindle (1994) and Gordon and Richardson (1989).

7. The EPA refers to land-based transportation control measures as both "smart growth" (2001a) and "sustainable" (1999) land use activities.

8. The state department of natural resources or environmental protection is generally charged with responsibility for formulating the state implementation plan.

9. The U.S. Department of Transportation requires cities of fifty thousand residents or more to prepare a long-range transportation plan and a short-term transportation improvement program (TIP). The transportation plan identifies the projected system improvements and maintenance that will be required over a period of at least twenty years. The TIP is the short-term spending plan for specific projects occurring typically within a three-year window. Through the transportation conformity review process, metropolitan planning organizations are required to demonstrate the conformity of both the transportation plan and the TIP with the mobile source emissions budget established in the state implementation plan (U.S. EPA 2001a).

10. It should be noted that metropolitan regions are only permitted to account for the air quality benefits of a land-based control strategy in one stage of the air quality planning process. Because each stage is performed sequentially, the inclusion of the same land use strategy in more than a single stage would lead to a "double counting" of benefits.

11. The TEA-21 reauthorization bill is titled the "Safe, Accountable, Flexible, and Efficient Transportation Equity Act of 2003" and is currently under review by the U.S. Congress

► References

Apogee Research, Inc. 1998. *The effects of urban form on travel and emissions: A review and synthesis of the literature.* HBIX reference C611-005. Washington, DC: U.S. Environmental Protection Agency.

Beatley, T. 2000. *Green urbanism: Learning from European cities.* Washington, DC: Island Press.

Boubel, R., D. Fox, D. Turner, and S. Stern. 1994. *Fundamentals of air pollution.* New York: Academic Press.

Boyer, P. 1978. *Urban masses and moral order in America: 1820-1920.* Cambridge, MA: Harvard University Press.

Brindle, R. 1994. Lies, damned lies and "automobile dependence"—Some hyperbolic reflections. *Australian Transport Research Forum* 19:117-31.

Bryner, G. 1993. *Blue skies, green politics: The Clean Air Act of 1990.* Washington, DC: CQ Press.

Cambridge Systematics, Inc. and Parsons, Brinkerhoff, Quade, and Douglas, Inc. 1996. *Making the land use, transportation, air quality connection: Analysis of alternatives.* Portland: 1,000 Friends of Oregon.

Cervero, R. 1998. *The transit metropolis: A global inquiry.* Washington, DC: Island Press.

———. 2003. Road expansion, urban growth, and induced travel: A path analysis. *Journal of the American Planning Association* 69 (2): 145-63.

Cervero, R., and R. Gorham. 1995. Commuting in transit versus automobile neighborhoods. *Journal of the American Planning Association* 61 (2): 210-25.

Cotton, P. 1993. Best data yet say air pollution kills below levels currently considered safe. *Journal of the American Medical Association* 269 (24): 3087-91.

Downs, A. 1992. *Stuck in traffic: Coping with peak-hour traffic congestion.* Washington, DC: Brookings Institution.

Dunphy, R., and K. Fisher. 1994. Transportation, congestion, and density: New insights. Paper presented at the seventy-third annual meeting of the Transportation Research Board, no. 940904, Washington, D.C., January.

Erbes, R. 1996. *A practical guide to air quality compliance.* New York: John Wiley.

Frank, L., and G. Pivo. 1994. Impacts of mixed use and density on utilization of three modes of travel: Single-occupant vehicle, transit, and walking. *Transportation Research Record* 1466:44-52.

Frank, L., B. Stone Jr., and W. Bachman. 2000. Linking land use with household vehicle emissions in the central Puget Sound: Methodological framework and findings. *Transportation Research—Part D: Transport and Environment* May:173-96.

Giuliano, G. 1995. The weakening transportation–land use connection. *Access* 6:3-11.

Giuliano, G., and K. Small. 1993. Is the journey to work explained by urban structure? *Urban Studies* 30 (9): 1485-1500.

Gordon, P., and H. Richardson. 1989. Gasoline consumption and cities: A reply. *Journal of the American Planning Association* 55 (3): 342-45.

Handy, S. 1992. Regional versus local accessibility: Neo-traditional development and its implications for non-work travel. *Built Environment* 18:253-67.

Hansen, M., and Y. Huang. 1997. Road supply and traffic in California urban areas. *Transportation Research Part A: Policy and Practice* 31 (3): 205-18.

Holtzclaw, J. 1994. *Using residential patterns and transit to decrease auto dependence and costs.* New York: Natural Resources Defense Council.

Jack Faucett Associates. 1998. *Background information for land use SIP policy.* EPA 420-R-98-012. Washington, DC: U.S. Environmental Protection Agency Office of Mobile Sources.

Johnston, R., C. Rodier, M. Choy, and J. Abraham. 2000. *Air quality impacts of regional land use policies.* Washington, DC: U.S. Environmental Protection Agency, Urban and Economic Development Division.

Kulash, W. 1991. Traditional neighborhood development: Will the traffic work? Paper presented at the Eleventh Annual Pedestrian Conference, Bellevue, WA, October.

Nelson, A. C. 1992. Preserving prime farmland in the face of urbanization. *Journal of the American Planning Association* 58 (4): 467-88.

Newman, P., and J. Kenworthy. 1989. Gasoline consumption and cities: A comparison of U.S. cities with a global survey and its implication. *Journal of the American Planning Association* 55 (1): 24-37.

———. 1999. *Sustainability and cities: Overcoming automobile dependence.* Washington, DC: Island Press.

Odell, E., D. Theobald, and R. Knight. 2003. Incorporating ecology into land use planning: The songbird's case for clustered development. *Journal of the American Planning Association* 69 (1): 72-81.

Ohm, B. 2000. The purchase of scenic easements and Wisconsin's great river road: A progress report on perpetuity. *Journal of the American Planning Association* 66 (2): 177-88.

Pucher, J., and C. Lefevre. 1996. *The urban transport crisis in Europe and North America.* London: Macmillan.

Putnam, R. 2000. *Bowling alone: The collapse and revival of American community.* New York: Simon & Schuster.

Schlesinger, P., and M. Horowitz. 1998. Regulation of mobile sources: Motor vehicles and nonroad engines. In *The Clean Air Act handbook,* edited by R. Martineau and D. Novello. Chicago: Bar Association Publishing.

Shprentz, D. 1996. *Premature mortality due to particulate air pollution in 239 American cities.* New York: Natural Resource Defense Council.

Southworth, Michael. 1997. Walkable suburbs? An evaluation of neotraditional communities at the urban edge. *Journal of the American Planning Association* 63 (1): 28-44.

Stradling, D. 1999. *Smokestacks and progressives: Environmentalists, engineers, and air quality in America, 1851-1951.* Baltimore: Johns Hopkins University Press.

Touloumi, G., K. Katsouyanni, D. Zmirou, J. Schwartz, C. Spix, A. Ponce de Leon, A. Tobias, P. Quennel, D. Rabczenko, L. Bacharova, L. Bisanti, J. M. Vonk, and A. Ponka. 1997. Short-term effects of ambient ozone exposure on mortality: A combined analysis within the APHEA project. *American Journal of Epidemiology* 146 (2): 177-85.

Transportation Research Board. 1995. *Expanding metropolitan highways: Implications for air quality and energy use: Special report 245.* Washington, DC: Transportation Research Board.

U.S. Department of Commerce. 1993. *Statistical abstract of the USA.* Washington, DC: Bureau of the Census.

U.S. Department of Energy. 2002. *Transportation energy data book: Edition 22.* DE-AC05-00R22725. Washington, DC: U.S. Department of Energy, Office of Planning, Budget Formulation, and Analysis.

U.S. Environmental Protection Agency. 1994. *Automobile emissions: An overview.* Fact sheet OMS-5, EPA 400-F-92-007. Washington, DC: U.S. Environmental Protection Agency, Office of Transportation and Air Quality.

———. 1999. *Granting air quality credit for land use measures: Policy options.* Report no. SR 99-09-01. Washington, DC: U.S. Environmental Protection Agency, Office of Air and Radiation.

———. 2000. *National air quality and emissions trends report, 1998.* EPA 454/R-00-003. Washington, DC: U.S. Environmental Protection Agency, Office of Air Quality.

———. 2001a. *EPA guidance: Improving air quality through land use activities.* EPA 420-R-01-001. Washington, DC: U.S. Environmental Protection Agency, Office of Transportation and Air Quality.

———. 2001b. *National air quality and emissions trends report, 1999.* EPA 454/R-01-004. Washington, DC: U.S. Environmental Protection Agency, Office of Air Quality.

Wyman, R., and M. Kato. 1998. Meeting ambient air standards: Development of the state implementation plans. In *The Clean Air Act handbook,* edited by R. Martineau and D. Novello. Chicago: American Bar Publishing.